SOLAR/1024-78/12

Monthly Performance Report

LIVING SYSTEMS

DECEMBER 1978

U.S. Department of Energy

National Solar Heating and Cooling Demonstration Program

National Solar Data Program

MONTHLY PERFORMANCE REPORT

LIVING SYSTEMS

DECEMBER 1978

I. SYSTEM DESCRIPTION

The Living Systems site is a single-family residence in Davis, California. The home has approximately 1700 square feet of conditioned space. The solar energy system consists of two independently controlled systems: An active system for preheating domestic-hot-water (DHW) and a passive system for space heating the home.

The active solar DHW system has an array of flat-plate collectors with a gross area of 46 square feet. The array faces south at an angle of 45 degrees to the horizontal. Potable city water is the transfer medium used throughout the system. When water in the collector is sufficiently warmer than that in the preheat tank, the controller starts the circulation between the preheat storage tank and the collector. The preheat tank holds 82-gallons and water is supplied, on demand, to a conventional 20-gallon DHW tank. When the water preheated by solar energy is not hot enough to satisfy the hot water load, a natural gas burner in the 20-gallon DHW tank provides auxiliary energy for water heating. The system is shown schematically in Figure 1.

The passive solar space heating system is of the direct-gain type illustrated schematically in Figure 2. Incident solar energy is admitted to the building through both the large south-facing vertical windows (approximately 200 square feet) and the overhead skylight (approximately 80 square feet at 60 degrees from the horizontal). Manually operated insulating curtains provide insulation during the night and sunless days for the south-facing collector windows; manually operated insulating shutters provide night insulation for the skylight glazing and are aluminum coated to provide reflection to the space below when open. Solar energy storage is provided by blue-painted steel water-filled tubes containing approximately 3600 gallons of water placed near the south window wall and under the skylight. Additional storage is provided by the 6-inch-thick concrete slab floor of the building which is covered by brown tiles. Collected solar energy is distributed by natural convection, by conduction through the slab, and by radiation. Floor covering is minimal: linoleum in the kitchen and eating area and white shag rugs in two bedrooms. The building envelope is well insulated in order to ensure energy conservation, with R-19 insulation in the walls and R-30 insulation in the roof. The effective R-value of the window areas with curtains and shutters in place is in the range of R-2 to R-10. All glass surfaces are double-glazed with minimum window area in nonsouth-facing walls. Auxiliary space heating is provided by a gas-fired wall furnace; as with the solar heating, natural convection distributes the heat. Additional auxiliary energy can be supplied from a wood-burning stove.

Building summer overheat protection is provided by several means: First, roof overhangs over the south-facing glazed areas provide shading; second,

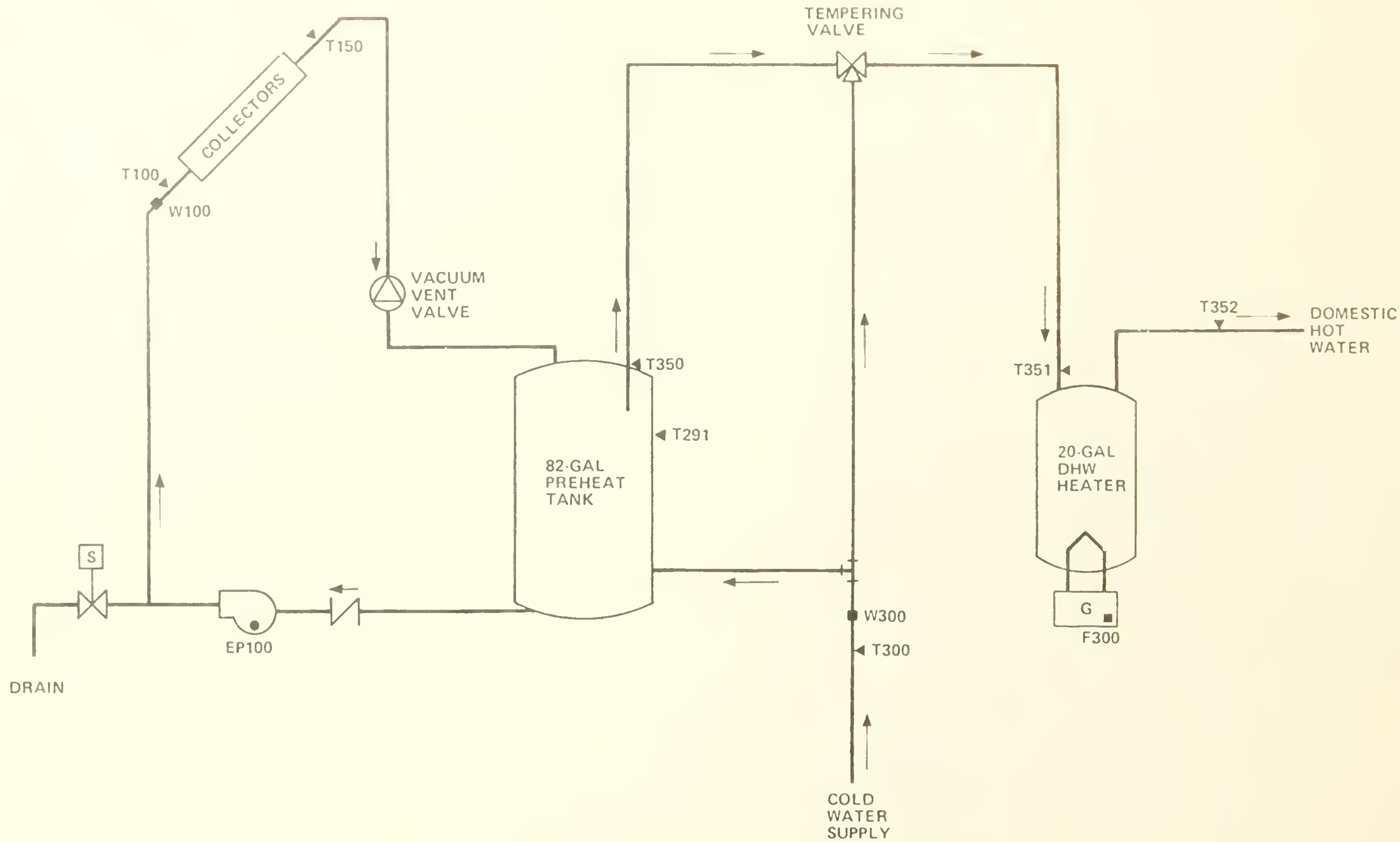

Figure 1. LIVING SYSTEMS ACTIVE SOLAR DOMESTIC HOT WATER SYSTEM SCHEMATIC

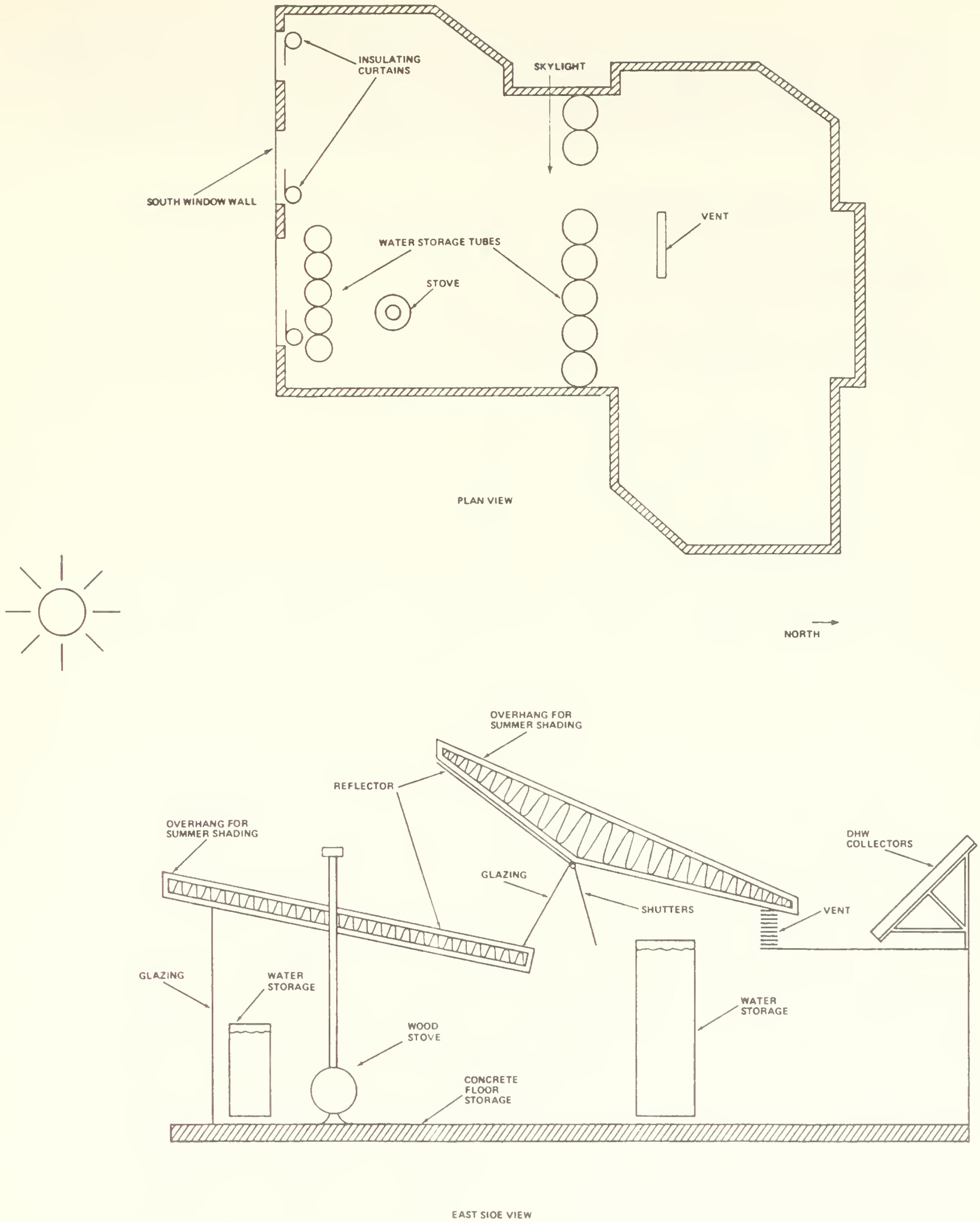

Figure 2. LIVING SYSTEMS PASSIVE SPACE HEATING SYSTEM

operable windows in the south wall along with a vent in the north wall are used for cross-ventilation of the house at night, cooling the solar storage mass and providing moderation of daytime building temperatures; third, the curtains and shutters over the windows can be closed during the day to prevent collection of incident solar energy. When necessary, a ceiling fan is available to assist distribution of heating and venting.

II. PERFORMANCE EVALUATION

INTRODUCTION

Performance evaluation is presented in two parts for this solar energy site: The first part covers the active solar DHW system; the second covers the passive solar space heating system.

The communications system was operable only during the last 16 days of the month and the active solar DHW system was extensively damaged by freezing on December 8. Only limited information is available on the active DHW system. The passive solar space heating system provided over 50 percent of the space heating demand during the month. Operation of the wood-burning stove during periods of low incident solar energy provided backup energy while reducing the space heating demand. Daily variations in building temperature were minimal, indicating the presence of substantial amounts of energy storage capacity. Comfort levels remained reasonable throughout the month.

WEATHER CONDITIONS, ACTIVE SOLAR DHW SYSTEM

During the month total incident solar energy on the DHW collector array was 0.86 million Btu for a daily average of 606 Btu per square foot. This was below the estimated average daily solar radiation for this geographical area during December of 943 Btu per square foot for a south-facing plane with a tilt of 45 degrees to the horizontal. The average ambient temperature during December was 38°F as compared with the long-term average for December of 46°F.

THERMAL PERFORMANCE, ACTIVE SOLAR DHW SYSTEM

Collector - The total incident solar radiation on the DHW collector array for the month of December was 0.86 million Btu. During the brief period of the month when the collector was operative, no information was available. During the portion of the month when the data was collected and the DHW collector was inoperative, the storage, pipes, sensors, etc. were still working. There was leakage of 0.061 million Btu from the passive heating system into the DHW preheat system, resulting in an effective collector array efficiency of 7 percent, based on total incident insolation. There was no operating energy required by the inoperative collector loop.

DHW Load - The DHW system consumed 0.061 million Btu of solar energy and 1.8 million Btu of auxiliary thermal energy (equivalent to 3.0 million Btu of

auxiliary fossil fuel energy) to satisfy a hot water load of 1.9 million Btu. The solar fraction of this load was 11 percent. The passive system spill-over resulted in fossil fuel energy savings of 0.10 million Btu. A daily average of 122 gallons of DHW was consumed at an estimated average temperature of 122°F delivered from the tank.

WEATHER CONDITIONS, PASSIVE SOLAR SPACE HEATING SYSTEM

During the month, total incident solar energy on the passive collector south windows and skylight was 5.4 million Btu for a daily average of 633 Btu per square foot. This was below the estimated average daily solar radiation for this geographical area during December of 982 Btu per square foot for a south-facing plane with a tilt of 60 degrees to the horizontal. The average ambient temperature during December was 38°F as compared with the long-term average for December of 46°F.

THERMAL PERFORMANCE, PASSIVE SOLAR SPACE HEATING SYSTEM

The total incident solar radiation on the collector windows for the month of December was 5.4 million Btu. The total solar energy for the month of December delivered to the space heating load was 4.4 million Btu, resulting in a collector array efficiency of 82 percent, based on total incident insolation. Auxiliary thermal energy of 3.7 million Btu (equivalent to 7.3 million Btu auxiliary fossil fuel energy) was added to satisfy a space heating load of 8.0 million Btu. This resulted in a fossil fuel energy savings of 7.3 million Btu. The solar fraction of this load was 55 percent. The average storage temperature for the month was 69°F.

On many days during December, the wood-burning stove was used to satisfy a measurable amount of the building load. The thermal energy derived from operation of the wood-burning stove is applied as a reduction to the building load; that is, the major difference between the building load and the space heating demand is the energy derived from operating the wood stove. During December, this renewable energy was approximately 1.9 million Btu. Assuming a wood stove energy conversion efficiency of 30 percent, this 1.9 million Btu is approximately equivalent to 21 percent of a cord of dry hardwood (such as oak). In terms of the savings of nonrenewable energy, this renewable thermal energy derived from the wood is equivalent to over 3.2 million Btu of fossil fuel energy.

The interior comfort level was given as 68°F in zone 1, the south end of the building, and 66°F in zone 2, the north end. The temperature difference occurs because comfort zone 2 is heated by conduction through the slab and walls, and by convection and infiltration associated with the doors. The cooler temperatures in the bedrooms do not seem objectionable.

OBSERVATIONS

During the month of December, the new owner was still moving in and not fully advised of the normal usage of a passive solar home. The insulative shutters, one of the back doors, and the insulative curtains were not fully operational.

During the December 23 to December 26 holiday season, measurement values were abnormal because the wood stove overheated; the windows and vent were opened and the fan was turned on, sometimes for an extended period on cloudy days. On December 27 the thermostat was raised and fossil fuel was used to heat passive storage.

Computed comfort levels inside the building were reasonable during the entire month in both zones of the building. Zone 1 was the primary collection and storage area of the house. The comfort level in zone 2 was slightly lower than that of zone 1 due to the method of transferring heat to zone 2. Daily variations in building temperature averaged only 6°F for the month with a maximum variation of 10°F centered on 70.5°F occurring on both December 15 and 16.

The DHW system froze on December 8, apparently due to an installation problem. The drain-down controls operated properly, but sufficient water remained in the collectors to freeze and destroy them. With the collectors inoperative, considerable spill-over of solar energy occurred from the passive system during that portion of the month when data was being collected.

ENERGY SAVINGS

The solar energy system provided a total fossil fuel energy savings of 7.4 million Btu. Although the DHW system was inoperative, it received an energy boost from the passive system for a fossil fuel savings of 0.10 million Btu. The space heating system contributed an energy savings of 7.3 million Btu.

III. ACTION STATUS

The active DHW system was inoperative and requires major repair; insulative shutters and curtains require some work by the grantee or owner. Boeing has to repair the wind direction indicator and has to replace the DHW collector flowmeter by the time the DHW system is repaired.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT
SITE SUMMARY

SITE: LIVING SYSTEMS (159-1) DAVIS, CALIFORNIA SOLAR/1046-78/12
REPORT PERIOD: DECEMBER,1978

SITE/SYSTEM DESCRIPTION:
THE LIVING SYSTEMS SOLAR DOMESTIC HOT WATER SYSTEM PROVIDES PREHEAT TO THE BUILDING DOMESTIC HOT WATER SYSTEM . THIS ACTIVE SYSTEM USES FLAT PLATE COLLECTORS (46 SQ.FT.) TO HEAT WATER DIRECTLY IN A 82 GALLON STORAGE TANK. AUXILIARY HOT WATER ENERGY IS PROVIDED BY NATURAL GAS IN THE 20 GALLON HOT WATER HEATER.

GENERAL SITE DATA:

INCIDENT SOLAR ENERGY	0.864 MILLION BTU
	18777 BTU/SQ.FT.
COLLECTED SOLAR ENERGY	0.000 MILLION BTU
	0 BTU/SQ.FT.
AVERAGE AMBIENT TEMPERATURE	38 DEGREES F
AVERAGE BUILDING TEMPERATURE	63 DEGREES F
ECSS SOLAR CONVERSION EFFICIENCY	0.07
ECSS OPERATING ENERGY	0.000 MILLION BTU
TOTAL SYSTEM OPERATING ENERGY	0.000 MILLION BTU
TOTAL ENERGY CONSUMED	2.977 MILLION BTU

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	1.886	N.A.	N.A.	1.886 MILLION BTU
SOLAR FRACTION	11	N.A.	N.A.	11 PERCENT
SOLAR ENERGY USED	0.061	N.A.	N.A.	0.061 MILLION BTU
OPERATING ENERGY	N.A.	N.A.	N.A.	0.000 MILLION BTU
AUX. THERMAL ENERGY	1.795	N.A.	N.A.	1.795 MILLION BTU
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. MILLION BTU
AUX. FOSSIL FUEL	2.992	N.A.	N.A.	2.992 MILLION BTU
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	0.000 MILLION BTU
FOSSIL SAVINGS	0.101	N.A.	N.A.	0.101 MILLION BTU

SYSTEM PERFORMANCE FACTOR: 0.630

* DENOTES UNAVAILABLE DATA
@ DENOTES NULL DATA
N.A. DENOTES NOT APPLICABLE DATA

REFERENCE: USER'S GUIDE TO THE MONTHLY PERFORMANCE REPORT OF THE NATIONAL SOLAR DATA PROGRAM,FEBRUARY 28,1978, SOLAR/0004-78/18

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT
SITE SUMMARY

SITE: LIVING SYSTEMS (159-1) DAVIS, CALIFORNIA SOLAR/1046-78/12
REPORT PERIOD: DECEMBER,1978

SITE/SYSTEM DESCRIPTION:
THE LIVING SYSTEMS SOLAR DOMESTIC HOT WATER SYSTEM PROVIDES PREHEAT TO THE BUILDING DOMESTIC HOT WATER SYSTEM . THIS ACTIVE SYSTEM USES FLAT PLATE COLLECTORS (46 SQ.FT.) TO HEAT WATER DIRECTLY IN A 82 GALLON STORAGE TANK. AUXILIARY HOT WATER ENERGY IS PROVIDED BY NATURAL GAS IN THE 20 GALLON HOT WATER HEATER.

GENERAL SITE DATA:

INCIDENT SOLAR ENERGY	0.911 GIGA JOULES
	213233 KJ/SQ.M.
COLLECTED SOLAR ENERGY	0.000 GIGA JOULES
	0 KJ/SQ.M.
AVERAGE AMBIENT TEMPERATURE	3 DEGREES C
AVERAGE BUILDING TEMPERATURE	17 DEGREES C
ECSS SOLAR CONVERSION EFFICIENCY	0.07
ECSS OPERATING ENERGY	0.000 GIGA JOULES
TOTAL SYSTEM OPERATING ENERGY	0.000 GIGA JOULES
TOTAL ENERGY CONSUMED	3.141 GIGA JOULES

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	1.990	N.A.	N.A.	1.990 GIGA JOULES
SOLAR FRACTION	11	N.A.	N.A.	11 PERCENT
SOLAR ENERGY USED	0.064	N.A.	N.A.	0.064 GIGA JOULES
OPERATING ENERGY	N.A.	N.A.	N.A.	0.000 GIGA JOULES
AUX. THERMAL ENG	1.894	N.A.	N.A.	1.894 GIGA JOULES
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. GIGA JOULES
AUX. FOSSIL FUEL	3.157	N.A.	N.A.	3.157 GIGA JOULES
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	0.000 GIGA JOULES
FOSSIL SAVINGS	0.107	N.A.	N.A.	0.107 GIGA JOULES

SYSTEM PERFORMANCE FACTOR: 0.630

* DENOTES UNAVAILABLE DATA
@ DENOTES NULL DATA
N.A. DENOTES NOT APPLICABLE DATA

REFERENCE: USER'S GUIDE TO THE MONTHLY PERFORMANCE REPORT OF THE NATIONAL SOLAR DATA PROGRAM,FEBRUARY 28,1978, SOLAR/0004-78/18

SOLAR HEATING AND COOLING DEMCNSTRATION PROGRAM

MCNTHLY REPCRT
ENERGY CCLLECTION AND STORAGE SUBSYSTEM (ECSS)

SITE: LIVING SYSTEMS (159-1) CAVIS, CALIFCRNIA SOLAR/1046-78/12
REPORT PERICC: DECEMBER,1978

DAY OF MONTH	INCIDENT SCLAR ENERGY MILLICN BTU	AMBIENT TEMP DEG-F	ENERGY TC LCADS MILLION BTU	AUX THERMAL TO ECSS MILLION BTU	ECSS OPERATING ENERGY MILLION BTU	ECSS ENERGY REJECTED MILLION BTU	ECSS SOLAR CONVERSION EFFICIENCY
1	*	*	*	N	*	N	*
2	*	*	*	O	*	O	*
3	*	*	*	T	*	T	*
4	*	*	*		*		*
5	*	*	*	A	*	A	*
6	*	*	*	P	*	P	*
7	*	*	*	P	*	P	*
8	*	*	*	L	*	L	*
9	*	*	*	I	*	I	*
10	*	*	*	C	*	C	*
11	*	*	*	A	*	A	*
12	*	*	*	B	*	B	*
13	*	*	*	L	*	L	*
14	*	*	*	E	*	E	*
15	*	*	*		*		*
16	0.032	39	0.001		0.000		0.045
17	0.005	45	0.002		0.000		0.436
18	0.006	41	0.001		0.000		0.194
19	0.081	38	0.001		0.000		0.018
20	C.070	36	C.002		0.000		0.027
21	0.073	40	0.001		0.000		0.017
22	0.004	33	0.002		0.000		0.408
23	0.001	36	0.002		0.000		1.575
24	C.000	38	0.002		0.000		4.897
25	0.000	38	0.002		0.000		18.622
26	C.000	37	0.002		0.000		0.000
27	0.001	38	0.005		0.000		10.298
28	C.010	39	0.002		0.000		0.175
29	0.026	36	0.001		0.000		0.048
30	0.075	35	0.003		0.000		0.043
31	0.063	33	0.002		0.000		0.031
SUM	0.864	-	0.061	N.A.	0.000	N.A.	-
AVG	0.028	38	0.002	N.A.	0.000	N.A.	0.070
NBS ID	Q001	N113			Q102		N111

* DENOTES UNAVAILABLE DATA.
@ DENOTES NULL DATA.
N.A. DENOTES NCT APPLICABLE CATA.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT
COLLECTOR ARRAY PERFORMANCE

SITE: LIVING SYSTEMS (159-1) DAVIS, CALIFORNIA SOLAR/1046-78/12
REPORT PERIOD: DECEMBER,1978

DAY OF MONTH	INCIDENT SOLAR ENERGY MILLION BTU	OPERATIONAL INCIDENT ENERGY MILLION BTU	COLLECTED SOLAR ENERGY MILLION BTU	DAYTIME AMBIENT TEMP DEG F	COLLECTOR ARRAY EFFICIENCY
1	*	*	*	*	*
2	*	*	*	*	*
3	*	*	*	*	*
4	*	*	*	*	*
5	*	*	*	*	*
6	*	*	*	*	*
7	*	*	*	*	*
8	*	*	*	*	*
9	*	*	*	*	*
10	*	*	*	*	*
11	*	*	*	*	*
12	*	*	*	*	*
13	*	*	*	*	*
14	*	*	*	*	*
15	*	*	*	*	*
16	0.032	0.000	0.000	44	0.000
17	0.005	0.000	0.000	47	0.000
18	0.006	0.000	0.000	45	0.000
19	0.081	0.000	0.000	46	0.000
20	0.070	0.000	0.000	45	0.000
21	0.073	0.000	0.000	50	0.000
22	0.004	0.000	0.000	36	0.000
23	0.001	0.000	0.000	38	0.000
24	0.000	0.000	0.000	*	0.000
25	0.000	0.000	0.000	38	0.000
26	0.000	0.000	0.000	37	0.000
27	0.001	0.000	0.000	39	0.000
28	0.010	0.000	0.000	40	0.000
29	0.026	0.000	0.000	40	0.000
30	0.075	0.000	0.000	41	0.000
31	0.063	0.000	0.000	41	0.000
SUM	0.864	0.000	0.000	-	-
AVG	0.028	0.000	0.000	42	0.000
NBSID	Q001		Q100		N100

* DENOTES UNAVAILABLE DATA.
@ DENOTES NULL DATA.
N.A. DENOTES NOT APPLICABLE DATA.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT
STORAGE PERFORMANCE

SITE: LIVING SYSTEMS (159-1) DAVIS, CALIFORNIA SOLAR/1046-78/12
REPORT PERIOD: DECEMBER,1978

DAY OF MONTH	ENERGY TO STORAGE MILLION BTU	ENERGY FROM STORAGE MILLION BTU	CHANGE IN STORED ENERGY MILLION BTU	STORAGE AVERAGE TEMP DEG F	STORAGE EFFICIENCY
1	*	*	N	N	N
2	*	*	O	O	O
3	*	*	T	T	T
4	*	*			
5	*	*	A	A	A
6	*	*	P	P	P
7	*	*	P	P	P
8	*	*	L	L	L
9	*	*	I	I	I
10	*	*	C	C	C
11	*	*	A	A	A
12	*	*	B	B	B
13	*	*	L	L	L
14	*	*	E	E	E
15	*	*			
16	0.000	0.000			
17	0.000	0.002			
18	0.000	0.001			
19	0.000	0.001			
20	0.000	0.001			
21	0.000	0.001			
22	0.000	0.001			
23	0.000	0.001			
24	0.000	0.001			
25	0.000	-0.006			
26	0.000	0.001			
27	0.000	-0.000			
28	0.000	0.001			
29	0.000	0.000			
30	0.000	0.002			
31	0.000	0.001			
SUM	0.000	0.013	N.A.	-	-
AVG	0.000	0.000	N.A.	N.A.	N.A.
NBS ID	Q200	Q201	Q202		N108

* DENOTES UNAVAILABLE DATA.
@ DENOTES NULL DATA.
N.A. DENOTES NOT APPLICABLE DATA.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT
HOT WATER SUBSYSTEM

SITE: LIVING SYSTEMS (159-1) DAVIS, CALIFORNIA SOLAR/1046-78/12
REPORT PERIOD: DECEMBER,1978

DAY OF MON.	HOT WATER LOAD MILLION BTU	SOLAR FR.OF LOAD PER CENT	SOLAR ENERGY USED MILLION BTU	OPER ENERGY MILLION BTU	AUX THERMAL USED MILLION BTU	AUX ELECT FUEL MILLION BTU	AUX FOSSIL FUEL MILLION BTU	ELECT ENERGY SAVINGS MILLION BTU	FOSSIL ENERGY SAVINGS MILLION BTU	SUP. WAT. TEMP DEG F	HOT WAT. TEMP DEG F	HOT WATER USED GAL
1	*	*	*	N	*	N	*	N	*	*	*	*
2	*	*	*	O	*	O	*	O	*	*	*	*
3	*	*	*	T	*	T	*	T	*	*	*	*
4	*	*	*		*		*		*	*	*	*
5	*	*	*	A	*	A	*	A	*	*	*	*
6	*	*	*	P	*	P	*	P	*	*	*	*
7	*	*	*	P	*	P	*	P	*	*	*	*
8	*	*	*	L	*	L	*	L	*	*	*	*
9	*	*	*	I	*	I	*	I	*	*	*	*
10	*	*	*	C	*	C	*	C	*	*	*	*
11	*	*	*	A	*	A	*	A	*	*	*	*
12	*	*	*	B	*	B	*	B	*	*	*	*
13	*	*	*	L	*	L	*	L	*	*	*	*
14	*	*	*	E	*	E	*	E	*	*	*	*
15	*	*	*		*		*		*	*	*	*
16	0.062	3	0.001		0.070		0.117		0.002	65	128	124
17	0.046	7	0.002		0.055		0.092		0.004	63	113	109
18	0.031	24	0.001		0.040		0.066		0.002	63	111	71
19	0.050	16	0.001		0.055		0.091		0.002	62	126	99
20	0.047	5	0.002		0.059		0.098		0.003	65	123	102
21	0.025	9	0.001		0.025		0.042		0.002	61	109	58
22	0.029	7	0.002		0.041		0.068		0.003	60	107	66
23	0.052	5	0.002		0.056		0.093		0.003	62	121	102
24	0.069	3	0.002		0.076		0.127		0.003	63	130	123
25	0.163	9	0.002		0.074		0.124		0.003	62	126	310
26	0.047	38	0.002		0.033		0.055		0.003	63	128	90
27	0.066	36	0.005		0.055		0.091		0.009	62	128	151
28	0.060	19	0.002		0.061		0.102		0.003	62	127	119
29	0.054	6	0.001		0.052		0.087		0.002	62	127	113
30	0.087	5	0.003		0.087		0.145		0.005	63	125	160
31	0.085	3	0.002		0.088		0.147		0.003	61	125	158
SUM	1.886	-	0.061	N.A.	1.795	N.A.	2.992	N.A.	0.101	-	-	3792
AVG	0.061	11	0.002	N.A.	0.058	N.A.	0.097	N.A.	0.003	63	122	122
NBS	Q302	N300	Q300	Q303	Q301	Q305	Q306	Q311	Q313	N305	N307	N308

* DENOTES UNAVAILABLE DATA.
@ DENOTES NULL DATA.
N.A. DENOTES NOT APPLICABLE DATA.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT
ENVIRONMENTAL SUMMARY

SITE: LIVING SYSTEMS (159-1) DAVIS, CALIFORNIA SOLAR/1046-78/12
REPORT PERIOD: DECEMBER,1978

DAY OF MONTH	TOTAL INSOLATION BTU/SQ.FT	DIFFUSE INSOLATION BTU/SQ.FT	AMBIENT TEMPERATURE DEG F	CAYTIME AMBIENT TEMP DEG F	RELATIVE HUMIDITY PERCENT	WIND DIRECTION DEGREES	WIND SPEED M.P.H.
1	*	N	*	*	*	*	*
2	*	O	*	*	*	*	*
3	*	T	*	*	*	*	*
4	*		*	*	*	*	*
5	*	A	*	*	*	*	*
6	*	P	*	*	*	*	*
7	*	P	*	*	*	*	*
8	*	L	*	*	*	*	*
9	*	I	*	*	*	*	*
10	*	C	*	*	*	*	*
11	*	A	*	*	*	*	*
12	*	B	*	*	*	*	*
13	*	L	*	*	*	*	*
14	*	E	*	*	*	*	*
15	*		*	*	*	*	*
16	686		39	44	79	*	3
17	110		45	47	99	*	8
18	126		41	45	96	*	3
19	1759		38	46	78	*	6
20	1514		36	45	80	*	2
21	1586		40	50	75	*	1
22	82		33	36	97	*	1
23	22		36	38	97	*	2
24	8		38	*	97	*	2
25	2		38	38	97	*	2
26	0		37	37	97	*	1
27	11		38	39	97	*	2
28	217		39	40	98	*	5
29	575		36	40	93	*	3
30	1632		35	41	85	*	3
31	1361		33	41	87	*	2
SUM	18777	N.A.	-	-	-	-	-
AVG	606	N.A.	38	42	91	*	3
NBS ID	Q001		N113			N115	N114

* DENOTES UNAVAILABLE DATA.
@ DENOTES NULL DATA.
N.A. DENOTES NOT APPLICABLE DATA.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT
SITE SUMMARY

SITE: LIVING SYSTEMS (159-2)   DAVIS, CALIFORNIA   SOLAR/1046-78/12
REPORT PERIOD: DECEMBER,1978

SITE/SYSTEM DESCRIPTION:
THE LIVING SYSTEMS PASSIVE SOLAR SPACE HEATING SYSTEM PROVIDES SPACE HEATING FOR A 1700 SQUARE FOOT SINGLE FAMILY DWELLING. THE LARGE SOUTH-FACING WINDOW WALL AND CLERESTORY SKYLIGHT PERMIT DIRECT WINTER SUN TO ENTER THE HOUSE. SOLAR ENERGY THERMAL STORAGE IS PROVIDED BY BOTH WATER FILLED TUBES AND THE CONCRETE SLAB FLOOR. MOVABLE SHUTTERS AND INSULATING CURTAINS PROVIDE CAPABILITY TO REDUCE NIGHT HEAT LOSSES. SUMMER OVERHEAT PROTECTION IS PROVIDED BY ROOF OVERHANGS AND BY NATURAL VENTILATION. AUXILIARY SPACE HEAT IS PROVIDED BY A NATURAL GAS FURNACE.

GENERAL SITE DATA:

INCIDENT SOLAR ENERGY	5.354 MILLION BTU
	19613 BTU/SQ.FT.
COLLECTED SOLAR ENERGY	4.007 MILLION BTU
	14677 BTU/SQ.FT.
AVERAGE AMBIENT TEMPERATURE	38 DEGREES F
AVERAGE BUILDING TEMPERATURE	63 DEGREES F
ECSS SOLAR CONVERSION EFFICIENCY	0.82
ECSS OPERATING ENERGY	N.A. MILLION BTU
TOTAL SYSTEM OPERATING ENERGY	N.A. MILLION BTU
TOTAL ENERGY CONSUMED	11.647 MILLION BTU

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	N.A.	8.045	N.A.	8.045 MILLION BTU
SOLAR FRACTION	N.A.	55	N.A.	55 PERCENT
SOLAR ENERGY USED	N.A.	4.395	N.A.	4.395 MILLION BTU
OPERATING ENERGY	N.A.	N.A.	N.A.	N.A. MILLION BTU
AUX. THERMAL ENERGY	N.A.	3.661	N.A.	3.661 MILLION BTU
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. MILLION BTU
AUX. FOSSIL FUEL	N.A.	7.273	N.A.	7.273 MILLION BTU
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	N.A. MILLION BTU
FOSSIL SAVINGS	N.A.	7.324	N.A.	7.324 MILLION BTU

SYSTEM PERFORMANCE FACTOR: 1.106

* DENOTES UNAVAILABLE DATA
@ DENOTES NULL DATA
N.A. DENOTES NOT APPLICABLE DATA

REFERENCE: USER'S GUIDE TO THE MONTHLY PERFORMANCE REPORT OF THE NATIONAL SOLAR DATA PROGRAM,FEBRUARY 28,1978, SOLAR/0004-78/18

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT
SITE SUMMARY

SITE: LIVING SYSTEMS (159-2) DAVIS, CALIFORNIA SOLAR/1046-78/12
REPORT PERIOD: DECEMBER,1978

SITE/SYSTEM DESCRIPTION:
THE LIVING SYSTEMS PASSIVE SOLAR SPACE HEATING SYSTEM PROVIDES SPACE HEATING FOR A 1700 SQUARE FOOT SINGLE FAMILY DWELLING. THE LARGE SOUTH-FACING WINDOW WALL AND CLERESTORY SKYLIGHT PERMIT DIRECT WINTER SUN TO ENTER THE HOUSE. SOLAR ENERGY THERMAL STORAGE IS PROVIDED BY BOTH WATER FILLED TUBES AND THE CONCRETE SLAB FLOOR. MOVABLE SHUTTERS AND INSULATING CURTAINS PROVIDE CAPABILITY TO REDUCE NIGHT HEAT LOSSES. SUMMER OVERHEAT PROTECTION IS PROVIDED BY ROOF OVERHANGS AND BY NATURAL VENTILATION. AUXILIARY SPACE HEAT IS PROVIDED BY A NATURAL GAS FURNACE.

GENERAL SITE DATA:

INCIDENT SOLAR ENERGY	5.649	GIGA JOULES
	222720	KJ/SQ.M.
COLLECTED SOLAR ENERGY	4.227	GIGA JOULES
	166666	KJ/SQ.M.
AVERAGE AMBIENT TEMPERATURE	3	DEGREES C
AVERAGE BUILDING TEMPERATURE	17	DEGREES C
ECSS SOLAR CONVERSION EFFICIENCY	0.82	
ECSS OPERATING ENERGY	N.A.	GIGA JOULES
TOTAL SYSTEM OPERATING ENERGY	N.A.	GIGA JOULES
TOTAL ENERGY CONSUMED	12.288	GIGA JOULES

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	N.A.	8.487	N.A.	8.487 GIGA JOULES
SOLAR FRACTION	N.A.	55	N.A.	55 PERCENT
SOLAR ENERGY USED	N.A.	4.636	N.A.	4.636 GIGA JOULES
OPERATING ENERGY	N.A.	N.A.	N.A.	N.A. GIGA JOULES
AUX. THERMAL ENG	N.A.	3.862	N.A.	3.862 GIGA JOULES
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. GIGA JOULES
AUX. FOSSIL FUEL	N.A.	7.673	N.A.	7.673 GIGA JOULES
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	N.A. GIGA JOULES
FOSSIL SAVINGS	N.A.	7.727	N.A.	7.727 GIGA JOULES

SYSTEM PERFORMANCE FACTOR: 1.106

* DENOTES UNAVAILABLE DATA
@ DENOTES NULL DATA
N.A. DENOTES NOT APPLICABLE DATA

REFERENCE: USER'S GUIDE TO THE MONTHLY PERFORMANCE REPORT OF THE NATIONAL SOLAR DATA PROGRAM,FEBRUARY 28,1978, SOLAR/0004-78/18

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT
COLLECTOR ARRAY PERFORMANCE

SITE: LIVING SYSTEMS (159-2) DAVIS, CALIFORNIA SOLAR/1046-78/12
REPORT PERIOD: DECEMBER,1978

DAY OF MONTH	INCIDENT SOLAR ENERGY MILLION BTU	OPERATIONAL INCIDENT ENERGY MILLION BTU	COLLECTED SOLAR ENERGY MILLION BTU	DAYTIME AMBIENT TEMP DEG F	COLLECTOR ARRAY EFFICIENCY
1	*	*	N	*	N
2	*	*	O	*	O
3	*	*	T	*	T
4	*	*		*	
5	*	*	A	*	A
6	*	*	P	*	P
7	*	*	P	*	P
8	*	*	L	*	L
9	*	*	I	*	I
10	*	*	C	*	C
11	*	*	A	*	A
12	*	*	B	*	B
13	*	*	L	*	L
14	*	*	E	*	E
15	*	*		*	
16	0.193	0.142		44	
17	0.030	0.022		47	
18	0.030	0.023		45	
19	0.509	0.380		46	
20	0.441	0.326		45	
21	0.457	0.343		50	
22	0.017	0.005		36	
23	0.003	0.002		38	
24	0.001	0.000		*	
25	0.000	0.000		38	
26	0.000	0.000		37	
27	0.002	0.001		39	
28	0.055	0.031		40	
29	0.164	0.122		40	
30	0.464	0.407		41	
31	0.398	0.300		41	
SUM	5.354	4.079	4.007	-	-
AVG	0.173	0.132	N.A.	42	N.A.
NBSID	Q001		Q100		N100

* DENOTES UNAVAILABLE DATA.
@ DENOTES NULL DATA.
N.A. DENOTES NOT APPLICABLE DATA.

SOLAR HEATING AND COOLING DEMONSTRATICN PROGRAM

MCNTHLY REPORT
SPACE HEATING SUBSYSTEM

SITE: LIVING SYSTEMS (159-2)   CAVIS, CALIFCRNIA   SOLAR/1046-78/12
REPORT PERIOC: DECEMBER,1978

DAY CF MON.	SPACE HEATING LOAD MILLION BTU	SOLAR FR.OF LOAD PCT	SOLAR ENERGY USED MILLION BTU	OPER ENERGY MILLICN BTU	AUX THERMAL USED MILLICN BTU	AUX ELECT FUEL MILLION BTU	AUX FOSSIL FUEL MILLICN BTU	ELECT ENERGY SAVINGS MILLION BTU	FOSSIL ENERGY SAVINGS MILLION BTU	BLDG TEMP DEG. F	AMB TEMP DEG. F
1	*	*	*	N	*	N	*	N	*	*	*
2	*	*	*	C	*	O	*	O	*	*	*
3	*	*	*	T	*	T	*	T	*	*	*
4	*	*	*		*		*		*	*	*
5	*	*	*	A	*	A	*	A	*	*	*
6	*	*	*	F	*	F	*	P	*	*	*
7	*	*	*	P	*	P	*	P	*	*	*
8	*	*	*	L	*	L	*	L	*	*	*
9	*	*	*	I	*	I	*	I	*	*	*
10	*	*	*	C	*	C	*	C	*	*	*
11	*	*	*	A	*	A	*	A	*	*	*
12	*	*	*	B	*	B	*	B	*	*	*
13	*	*	*	L	*	L	*	L	*	*	*
14	*	*	*	E	*	E	*	E	*	*	*
15	*	*	*		*		*		*	*	*
16	0.232	48	0.111		0.121		0.238		0.185	66	39
17	0.257	83	0.212		0.045		0.101		0.353	65	45
18	0.292	51	0.148		0.144		0.279		0.247	62	41
19	0.322	57	0.183		0.138		0.273		0.306	63	38
20	0.356	56	0.200		0.156		0.306		0.334	64	36
21	0.304	88	0.267		0.037		0.086		0.445	64	40
22	0.304	84	0.256		0.048		0.107		0.427	61	33
23	0.053	81	0.042		0.010		0.030		0.071	62	36
24	0.177	52	0.093		0.089		0.182		0.154	63	38
25	0.174	28	0.049		0.125		0.246		0.081	62	38
26	0.214	15	0.031		0.175		0.339		0.052	62	37
27	0.290	-3	-0.008		C.298		0.573		-0.014	63	38
28	0.286	32	0.092		0.194		0.375		0.153	62	39
29	0.275	47	0.128		0.146		0.285		0.214	61	36
30	0.332	62	0.207		0.134		0.265		0.344	62	35
31	0.286	90	0.257		0.028		0.069		0.429	62	33
SUM	8.045	-	4.395	N.A.	3.661	N.A.	7.273	N.A.	7.324	-	-
AVG	0.260	55	0.142	N.A.	0.118	N.A.	0.235	N.A.	0.236	63	38
NBS	Q402	N400	Q400	Q403	C401		Q410	Q415	Q417	N406	N113

* DENCTES UNAVAILABLE DATA.
@ DENOTES NULL DATA.
N.A. DENOTES NCT APPLICABLE CATA.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT
ENVIRONMENTAL SUMMARY

SITE: LIVING SYSTEMS (159-2)   DAVIS, CALIFORNIA   SOLAR/1046-78/12
REPORT PERIOD: DECEMBER,1978

DAY OF MONTH	TOTAL INSOLATION BTU/SQ.FT	DIFFUSE INSOLATION BTU/SQ.FT	AMBIENT TEMPERATURE DEG F	DAYTIME AMBIENT TEMP DEG F	RELATIVE HUMIDITY PERCENT	WIND DIRECTION DEGREES	WIND SPEED M.P.H.
1	*	N	*	*	*	*	*
2	*	O	*	*	*	*	*
3	*	T	*	*	*	*	*
4	*		*	*	*	*	*
5	*	A	*	*	*	*	*
6	*	P	*	*	*	*	*
7	*	P	*	*	*	*	*
8	*	L	*	*	*	*	*
9	*	I	*	*	*	*	*
10	*	C	*	*	*	*	*
11	*	A	*	*	*	*	*
12	*	B	*	*	*	*	*
13	*	L	*	*	*	*	*
14	*	E	*	*	*	*	*
15	*		*	*	*	*	*
16	708		39	44	79	*	3
17	109		45	47	99	*	8
18	110		41	45	96	*	3
19	1863		38	46	78	*	6
20	1617		36	45	80	*	2
21	1673		40	50	75	*	1
22	61		33	36	97	*	1
23	11		36	38	97	*	2
24	4		38	*	97	*	2
25	1		38	38	97	*	2
26	0		37	37	97	*	1
27	8		38	39	97	*	2
28	202		39	40	98	*	5
29	600		36	40	93	*	3
30	1699		35	41	85	*	3
31	1456		33	41	87	*	2
SUM	19613	N.A.	-	-	-	-	-
AVG	633	N.A.	38	42	91	*	3
NBS ID	Q001		N113			N115	N114

* DENOTES UNAVAILABLE DATA.
@ DENOTES NULL DATA.
N.A. DENOTES NOT APPLICABLE DATA.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT
PASSIVE SPACE HEATING

SITE: LIVING SYSTEMS (159-2)   DAVIS, CALIFORNIA   SOLAR/1046-78/12
REPORT PERIOD: DECEMBER,1978

DAY OF MON	SPACE HEATING LOAD MILLION BTU	SOLAR ENERGY USED MILLION BTU	CHANGE IN STORE ENERGY MILLION BTU	AVERAGE STORAGE TEMP DEG F	DIRECT SOLAR UTIL EFFIC	AUX THERMAL USED MILLION BTU	BLDG TEMP DEG F	AMB TEMP DEG F	WIND AVG SPEED MPH	WIND AVG DIR DEG	SOLA FR LOAD PER CENT
1	*	*	*	*	*	*	*	*	*	*	*
2	*	*	*	*	*	*	*	*	*	*	*
3	*	*	*	*	*	*	*	*	*	*	*
4	*	*	*	*	*	*	*	*	*	*	*
5	*	*	*	*	*	*	*	*	*	*	*
6	*	*	*	*	*	*	*	*	*	*	*
7	*	*	*	*	*	*	*	*	*	*	*
8	*	*	*	*	*	*	*	*	*	*	*
9	*	*	*	*	*	*	*	*	*	*	*
10	*	*	*	*	*	*	*	*	*	*	*
11	*	*	*	*	*	*	*	*	*	*	*
12	*	*	*	*	*	*	*	*	*	*	*
13	*	*	*	*	*	*	*	*	*	*	*
14	*	*	*	*	*	*	*	*	*	*	*
15	*	*	*	*	*	*	*	*	*	*	*
16	0.231	0.110	0.048	72.4	0.573	0.120	66	39	3.0	*	48
17	0.256	0.211	-0.203	70.9	7.118	0.044	65	45	7.7	*	83
18	0.291	0.148	-0.120	67.7	4.929	0.143	62	41	2.5	*	51
19	0.321	0.183	0.131	68.4	0.361	0.138	63	38	5.6	*	57
20	0.356	0.200	0.073	70.4	0.454	0.156	64	36	1.6	*	56
21	0.304	0.266	0.002	71.0	0.584	0.037	64	40	1.4	*	88
22	0.304	0.256	-0.247	68.2	15.492	0.048	61	33	1.0	*	84
23	0.052	0.042	0.075	67.7	14.527	0.010	62	36	1.9	*	81
24	0.177	0.092	-0.042	68.9	79.989	0.088	63	38	2.2	*	52
25	0.173	0.048	0.000	68.2	159.850	0.125	62	38	2.1	*	28
26	0.213	0.031	0.039	67.9	0.000	0.174	62	37	1.5	*	15
27	0.289	-0.008	0.012	68.6	-3.623	0.297	63	38	1.8	*	-3
28	0.285	0.091	-0.054	67.2	1.663	0.194	62	39	4.9	*	32
29	0.274	0.128	-0.031	66.9	0.783	0.146	61	36	3.1	*	47
30	0.331	0.206	0.070	68.0	0.445	0.134	62	35	3.1	*	62
31	0.285	0.257	0.043	69.1	0.647	0.028	62	33	2.1	*	90
SUM	8.044	4.394	-0.387	-	-	3.660	-	-	-	-	-
AVG	0.259	0.141	-0.012	68.8	0.821	0.118	63	38	2.8	*	55
NBS	Q402	Q400	Q202			Q401	N405	N113	N114	N115	N400

* DENOTES UNAVAILABLE DATA.
@ DENOTES NULL DATA.
N.A. DENOTES NOT APPLICABLE DATA.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT
PASSIVE SYSTEM ENVIRONMENT

SITE: LIVING SYSTEMS (159-2) DAVIS, CALIFORNIA SOLAR/1046-78/12
REPORT PERIOD: DECEMBER,1978

DAY OF MON	BUILDING COMFORT ZONE 1	BLDG COMF ZONE 2	BUILDING TEMP MIDNIGHT DEG F	BUILDING TEMP 6 AM DEG F	BUILDING TEMP NOON DEG F	BUILDING TEMP 6 PM DEG F	INTERIOR RELATIVE HUMIDITY PERCENT	AMB TEMP DEG F	DAYTIME AMB TEMP DEG F	INCIDENT SOLAR ENERGY MILLION BTU	AVG STOR TEMP DEG F
1	*	*	*	*	*	*	*	*	*	*	*
2	*	*	*	*	*	*	*	*	*	*	*
3	*	*	*	*	*	*	*	*	*	*	*
4	*	*	*	*	*	*	*	*	*	*	*
5	*	*	*	*	*	*	*	*	*	*	*
6	*	*	*	*	*	*	*	*	*	*	*
7	*	*	*	*	*	*	*	*	*	*	*
8	*	*	*	*	*	*	*	*	*	*	*
9	*	*	*	*	*	*	*	*	*	*	*
10	*	*	*	*	*	*	*	*	*	*	*
11	*	*	*	*	*	*	*	*	*	*	*
12	*	*	*	*	*	*	*	*	*	*	*
13	*	*	*	*	*	*	*	*	*	*	*
14	*	*	*	*	*	*	*	*	*	*	*
15	*	*	66	*	*	65	*	*	*	*	*
16	72	69	68	64	64	67	28	39	44	0.193	72
17	69	69	63	66	65	65	35	45	47	0.030	71
18	66	66	62	63	62	62	37	41	45	0.030	68
19	68	66	64	59	66	66	32	38	46	0.509	68
20	70	68	64	61	67	66	29	36	45	0.441	70
21	70	68	63	60	68	67	30	40	50	0.457	71
22	66	66	61	60	60	61	32	33	36	0.017	68
23	67	65	64	61	61	65	32	36	38	0.003	68
24	69	65	62	64	62	63	33	38	*	0.001	69
25	68	64	64	62	61	64	31	38	38	0.000	68
26	68	65	63	61	61	63	33	37	37	0.000	68
27	69	66	63	63	63	64	31	38	39	0.002	69
28	67	66	64	59	62	63	33	39	40	0.055	67
29	66	65	59	61	61	62	33	36	40	0.164	67
30	68	66	51	59	64	63	29	35	41	0.464	68
31	69	66	63	59	64	64	29	33	41	0.398	69
SUM	-	-	-	-	-	-	-	-	-	5.354	-
AVG	68	66	63	61	63	64	32	38	42	0.173	69
NBS								N113			

* DENOTES UNAVAILABLE DATA.
@ DENOTES NULL DATA.
N.A. DENOTES NOT APPLICABLE DATA.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT
NORMALIZED PASSIVE SPACE HEATING

SITE: LIVING SYSTEMS (159-2) DAVIS, CALIFORNIA SOLAR/1046-78/12
REPORT PERIOD: DECEMBER,1978

DAY OF MONTH	AVG NORM SPACE HEAT FACTOR 1000/SQ FT	NORM HEATING LOAD MBTU/SQ FT	NORM AUX THERMAL MBTU/SQ FT	NORM ELECTRIC SAVINGS MBTU/SQ FT	NORM FOSSIL SAVINGS MBTU/SQ FT	HTG DEG DAYS
1	*	*	*	N	*	*
2	*	*	*	O	*	*
3	*	*	*	T	*	*
4	*	*	*		*	*
5	*	*	*	A	*	*
6	*	*	*	P	*	*
7	*	*	*	P	*	*
8	*	*	*	L	*	*
9	*	*	*	I	*	*
10	*	*	*	C	*	*
11	*	*	*	A	*	*
12	*	*	*	B	*	*
13	*	*	*	L	*	*
14	*	*	*	E	*	*
15	*	*	*		*	*
16	0.0000	149	81		114	27
17	0.0000	175	29		243	20
18	0.0000	218	105		188	21
19	0.0000	224	96		213	25
20	0.0000	238	108		217	28
21	0.0000	205	27		297	24
22	0.0000	227	36		318	27
23	0.0000	39	7		53	26
24	0.0000	129	61		112	25
25	0.0000	129	93		59	24
26	0.0000	155	132		38	26
27	0.0000	203	209		-10	25
28	0.0000	214	144		116	23
29	0.0000	204	109		159	25
30	0.0000	242	96		243	26
31	0.0000	204	22		303	29
SUM	-	5722	2626	N.A.	5160	779
AVG	0.0000	185	626	N.A.	166	25
NBS ID						

* DENOTES UNAVAILABLE DATA.
@ DENOTES NULL DATA.
N.A. DENOTES NOT APPLICABLE DATA.